Slope Mass Rating (SMR) charts for onsite classification of rock slopes

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Abstract

The slope mass rating (SMR) method is universally used for the characterization and classification of rock slopes. SMR is calculated by reducing the value of basic rock mass rating (RMRb) by subtracting three adjustment factors F1, F2, and F3 based on the geometrical relationship between the slope and discontinuity and adding one adjustment factor F4 depending upon the excavation method used. These adjustment factors (F1, F2, and F3) are mathematical functions (continuous/discrete) that require post-processing of field data on a computer for their derivation. Less work has been done to develop the charts for the direct calculation of SMR in the field. In this paper, SMR charts are developed for the onsite classification of rock slopes. With the aid of SMR charts, an engineering geologist can easily assess the onsite SMR class of rock slopes by plotting discontinuity dip amount (plunge amount in case of wedge failure) and strike parallelism between slope dip direction and discontinuity dip direction (slope dip direction and trend direction of intersection line in case of wedge failure). Using SMR charts for any project (open-pit mines, road cut slopes, natural slopes, etc.) onsite suggestions of proper remedial and preventive measures for the rock slopes can be given, which accelerates the overall preliminary slope mass classification process. The proposed SMR charts are straightforward to use and can be adopted as useful tools for the preliminary rock slope stability assessment.

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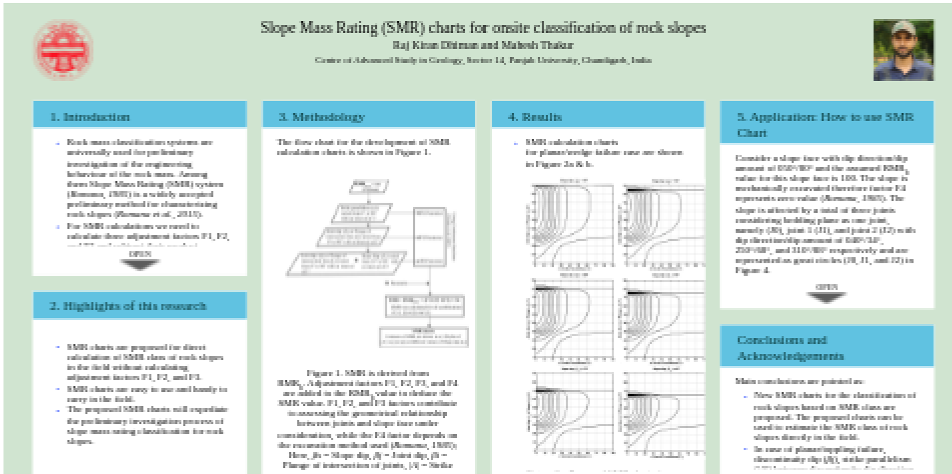

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1. INTRODUCTION

- Rock mass classification systems are universally used for preliminary investigation of the engineering behaviour of the rock mass. Among them Slope Mass Rating (SMR) system (*Romana, 1985*) is a widely accepted preliminary method for characterizing rock slopes (*Romana et al., 2015*).
- For SMR calculations we need to calculate three adjustment factors F1, F2, and F3 and subtract their product (F1×F2×F3) from the basic rock mass rating (RMR_b) and add one factor (F4) for the excavation method used to get the final SMR value for a rock slope as per equation 1, $SMR = RMR_b + (F1 * F2 * F3) + F4$
- F1, F2, and F3 are continuous mathematical functions (*Tomás et al. 2007*) and require a computer for their calculation.
- From the year 2007, when continuous functions for SMR were introduced until today, no significant work has been done to develop the charts for the direct calculation of SMR in the field using continuous functions.
- In this research, we propose SMR charts that can be used to estimate the onsite SMR class of a rock slope. The use of SMR charts eliminates the derivation of F1, F2, and F3 parameters and directly estimates the SMR class of rock slope in the field.

2. HIGHLIGHTS OF THIS RESEARCH

- SMR charts are proposed for direct calculation of SMR class of rock slopes in the field without calculating adjustment factors F1, F2, and F3.
- SMR charts are easy to use and handy to carry in the field.
- The proposed SMR charts will expediate the preliminary investigation process of slope mass rating classification for rock slopes.

3. METHODOLOGY

The flow chart for the development of SMR calculation charts is shown in Figure 1.

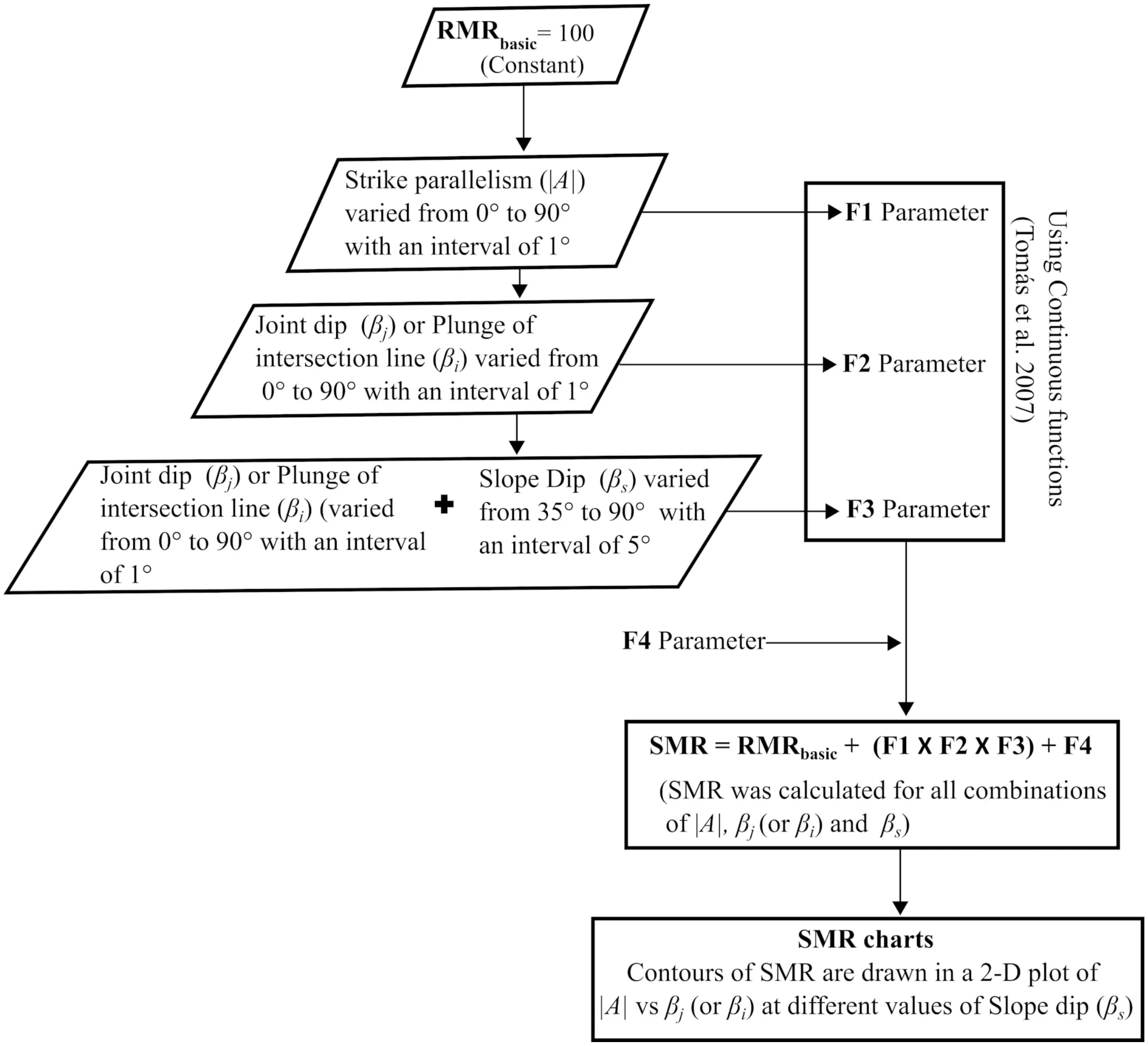

Figure 1. SMR is derived from RMR$_b$. Adjustment factors F1, F2, F3, and F4 are added to the RMR$_b$ value to deduce the SMR value. F1, F2, and F3 factors contribute to assessing the geometrical relationship between joints and slope face under consideration, while the F4 factor depends on the excavation method used (*Romana, 1985*); Here, βs = Slope dip, βj = Joint dip, βi = Plunge of intersection of joints, $|A|$ = Strike parallelism between joints and slope OR intersection line and slope.

4. RESULTS

- SMR calculation charts for planar/wedge failure case are shown in Figure 2a & b.

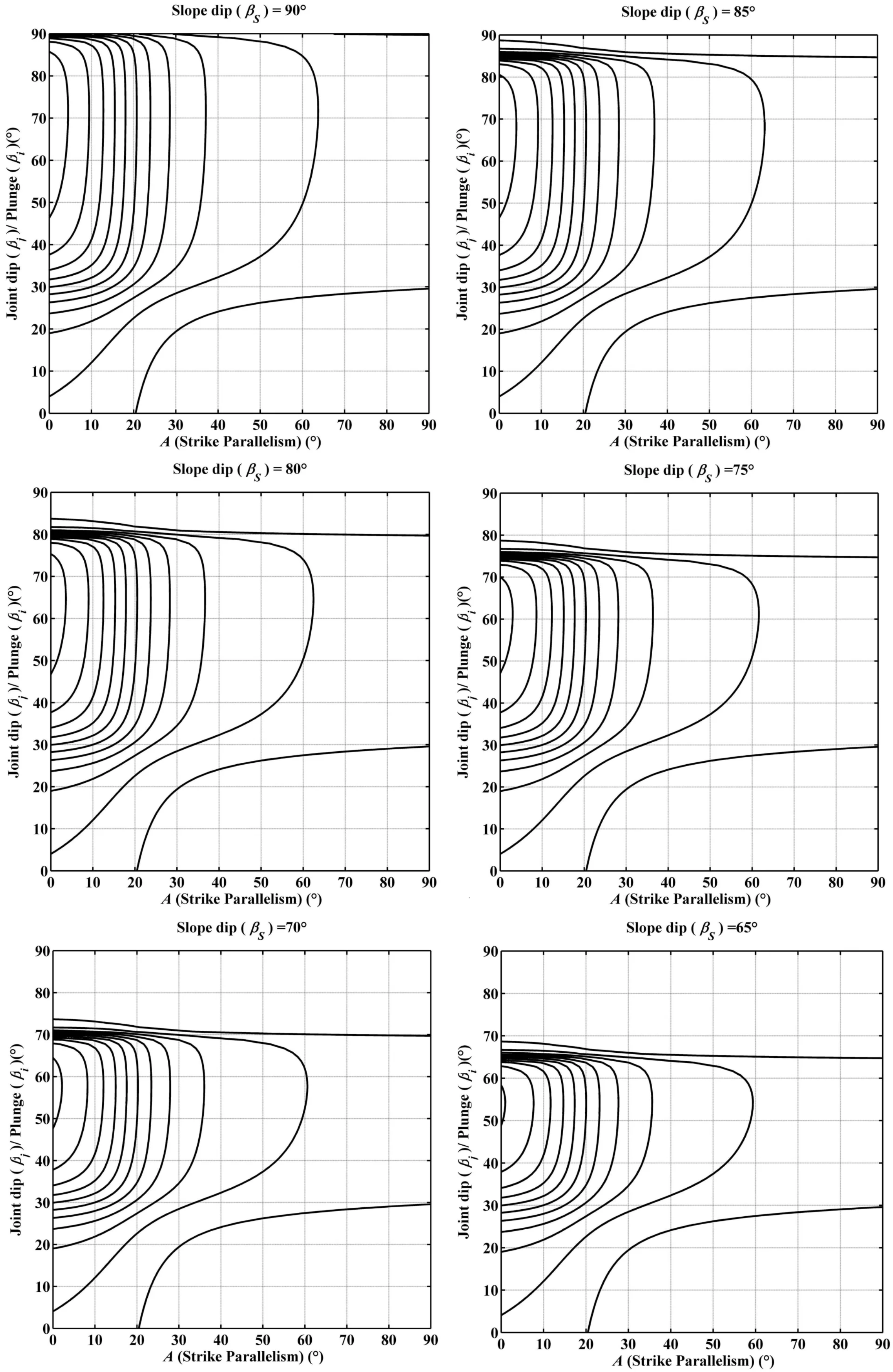

Figure 2a. Proposed SMR charts for planar/wedge failure case, (65°<βs<90°).

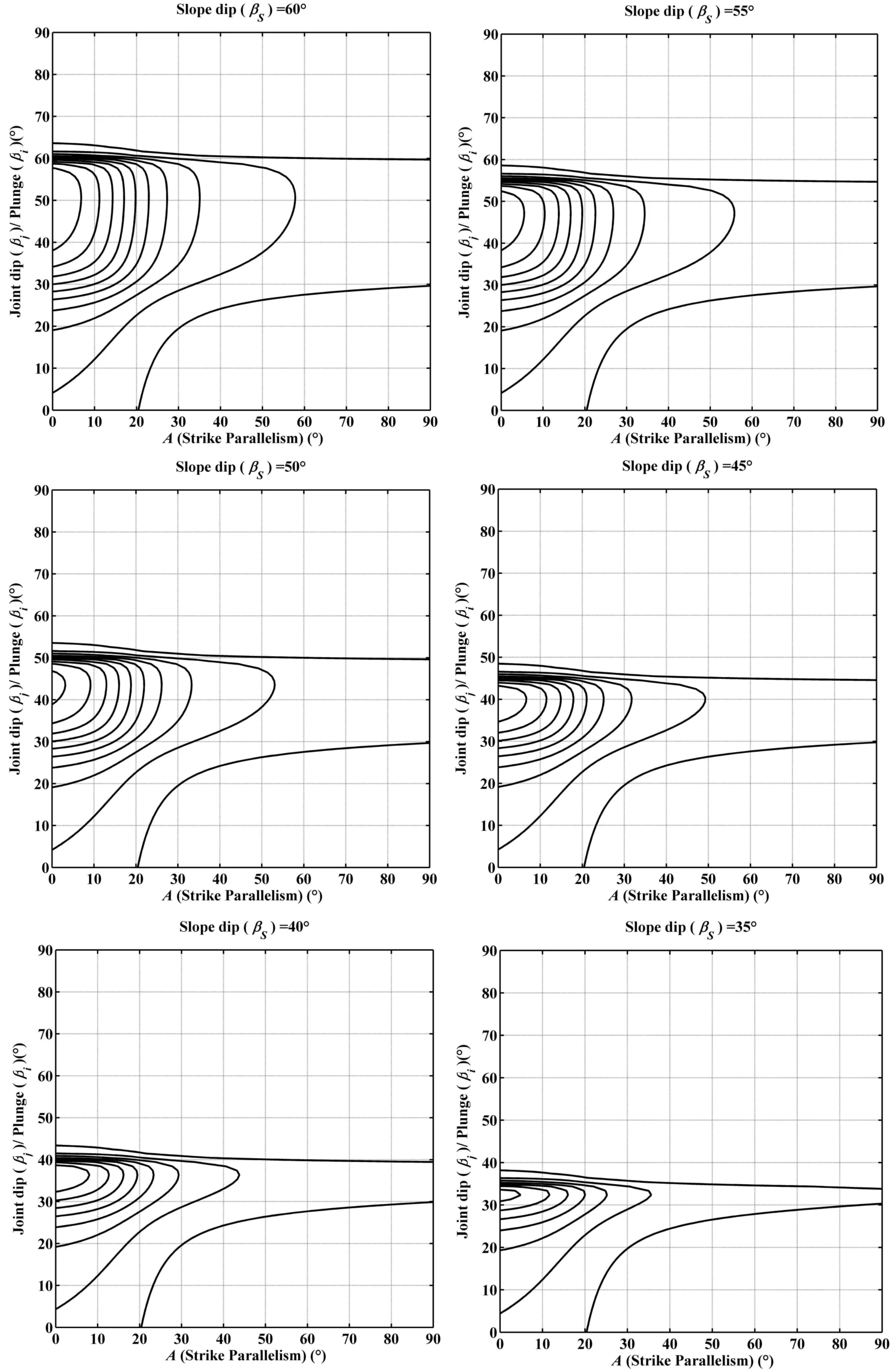

Figure 2b. Proposed SMR charts for planar/wedge failure case, (35°<βs<60°).

- SMR calculation charts for toppling failure case are shown in Figure 3a & b.

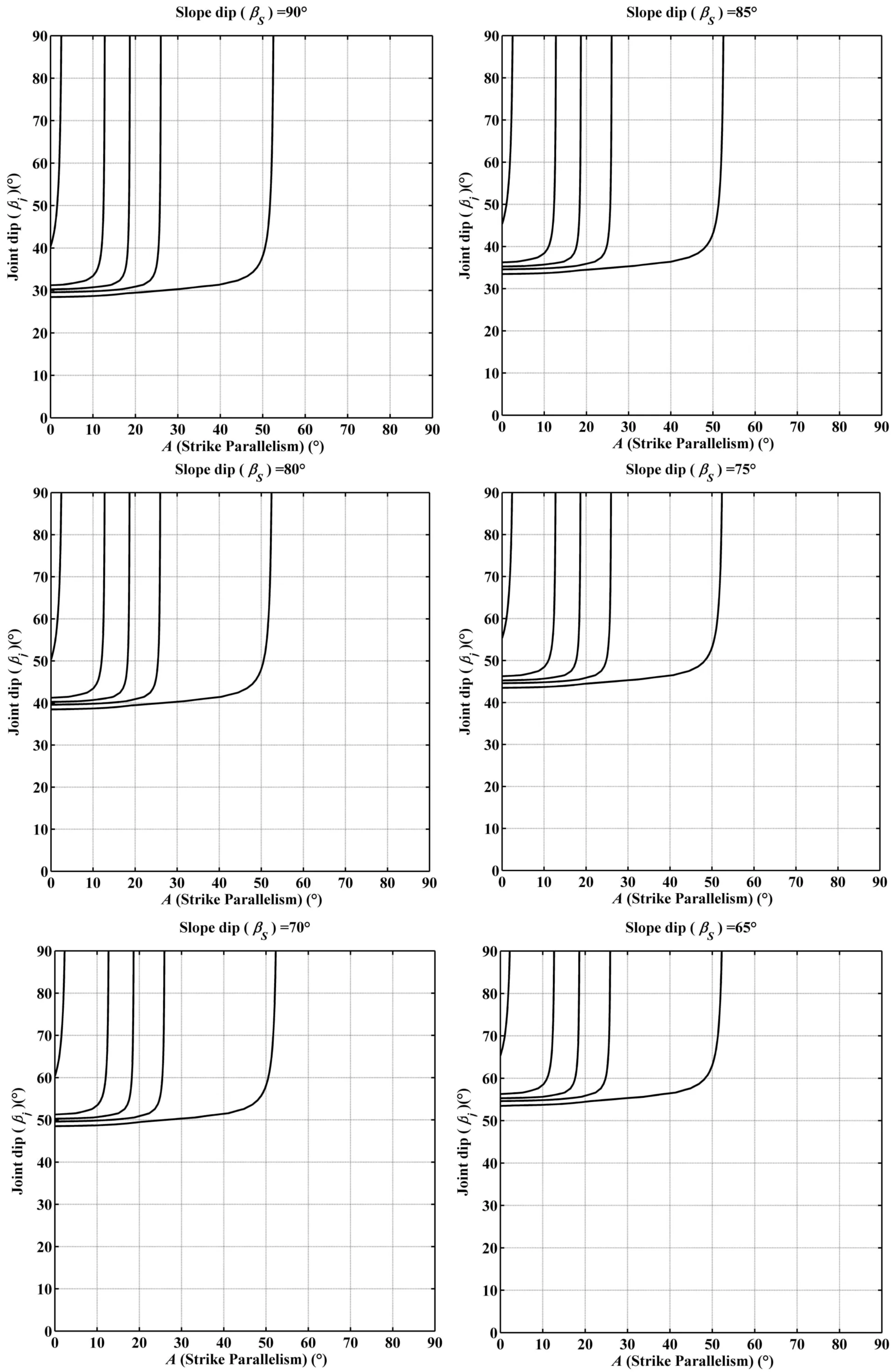

Figure 3a. Proposed SMR charts for planar/wedge failure case, (65°<βs<90°).

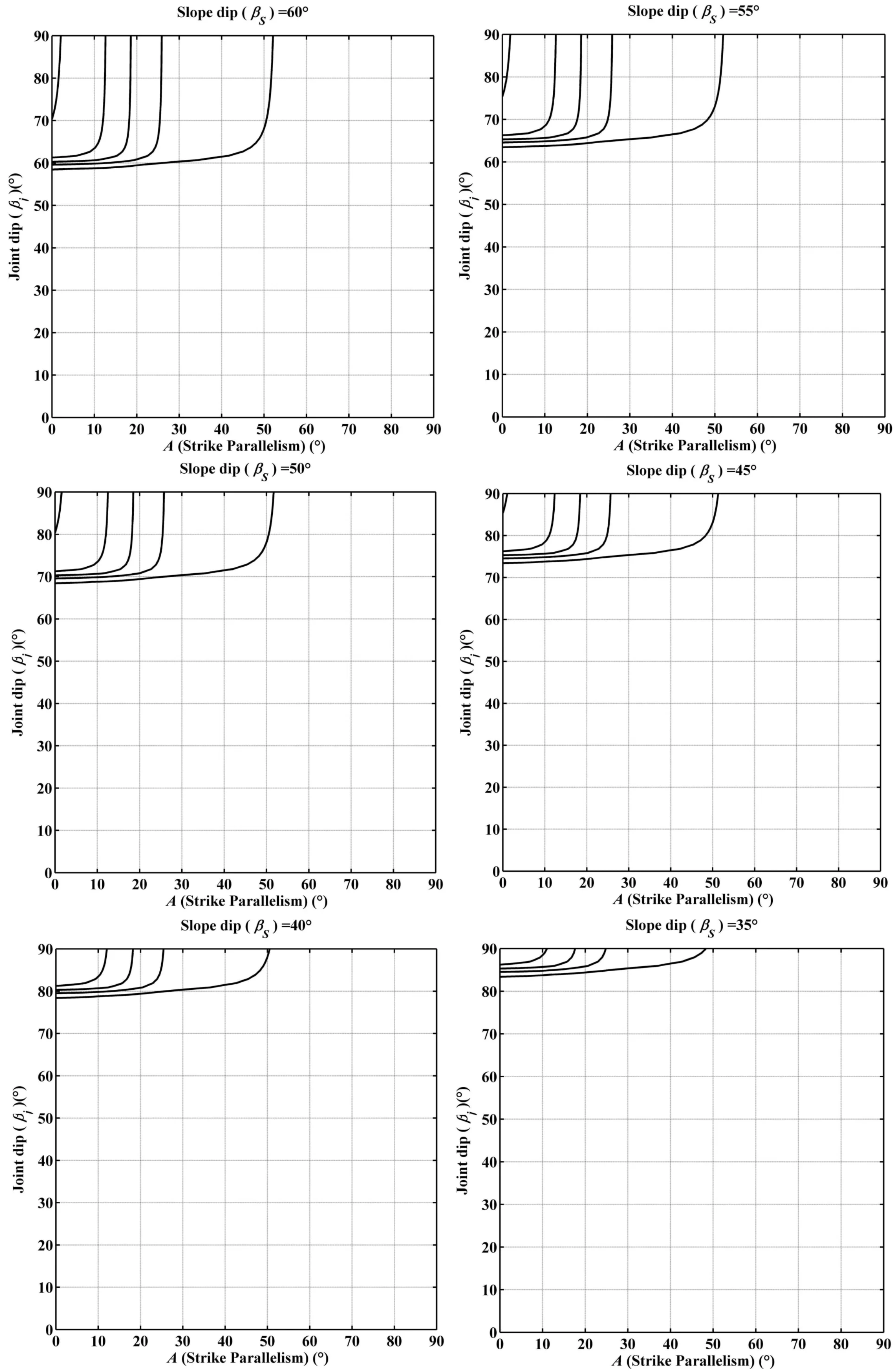

Figure 3b. Proposed SMR charts for planar/wedge failure case, (35°<βs <60°).

5. APPLICATION: HOW TO USE SMR CHART

Consider a slope face with dip direction/dip amount of 050°/80° and the assumed RMR_b value for this slope face is 100. The slope is mechanically excavated therefore factor F4 represents zero value (*Romana, 1985*). The slope is affected by a total of three joints considering bedding plane as one joint, namely (J0), joint 1 (J1), and joint 2 (J2) with dip direction/dip amount of 040°/34°, 250°/68°, and 310°/88° respectively and are represented as great circles (J0, J1, and J2) in Figure 4.

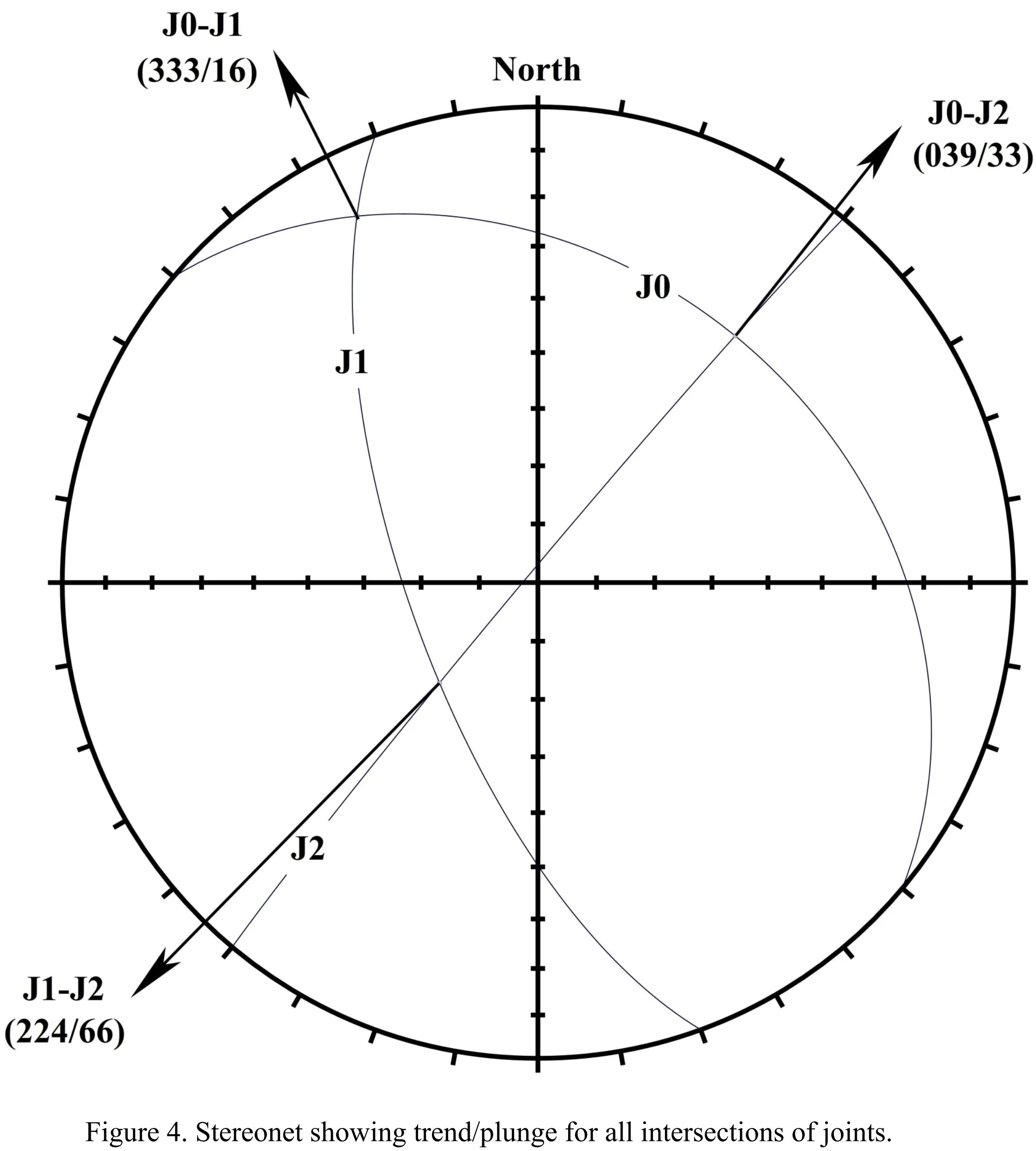

Figure 4. Stereonet showing trend/plunge for all intersections of joints.

Strike parallelism for joints and intersections is shown in Figure 5.

Slope face	Dip direction (in °)	Dip amount,						
	050	80						
Failure mode			Planar failure	Toppling failure	Wedge failure			
Joints	Dip direction, (in °)	Dip amount, (in °)	Strike Parallelism (A) (in °)	Strike Parallelism (A) (in °)	Intersections	Trend, (in °)	Plunge, (in °)	Strike Parallelism (A) (in °)
J0	040	34	10	170	J0-J1	333	16	77
J1	250	68	160	20	J0-J2	039	33	11
J2	310	88	100	80	J1-J2	224	66	174

Figure 5. Calculation of parameter strike parallelism $|A|$ in case of the planar, wedge, and toppling failure mode for the assumed slope.

- Planar SMR calculation using SMR chart (Figure 6a):

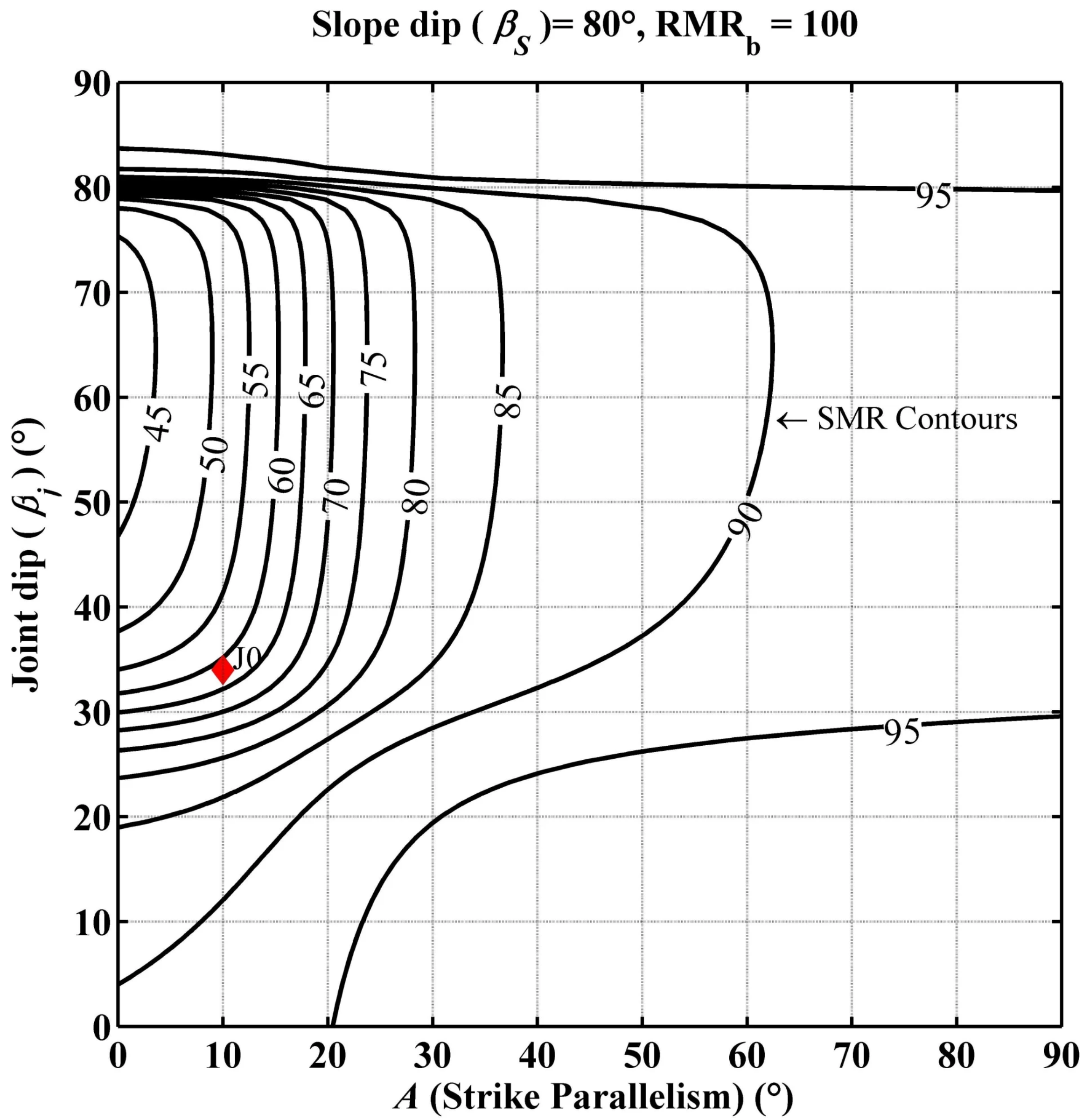

Figure 6a. Joint dip (*βj*) vs strike parallelism |*A*| in case of planar failure

- Wedge SMR calculation using SMR chart (Figure 6b):

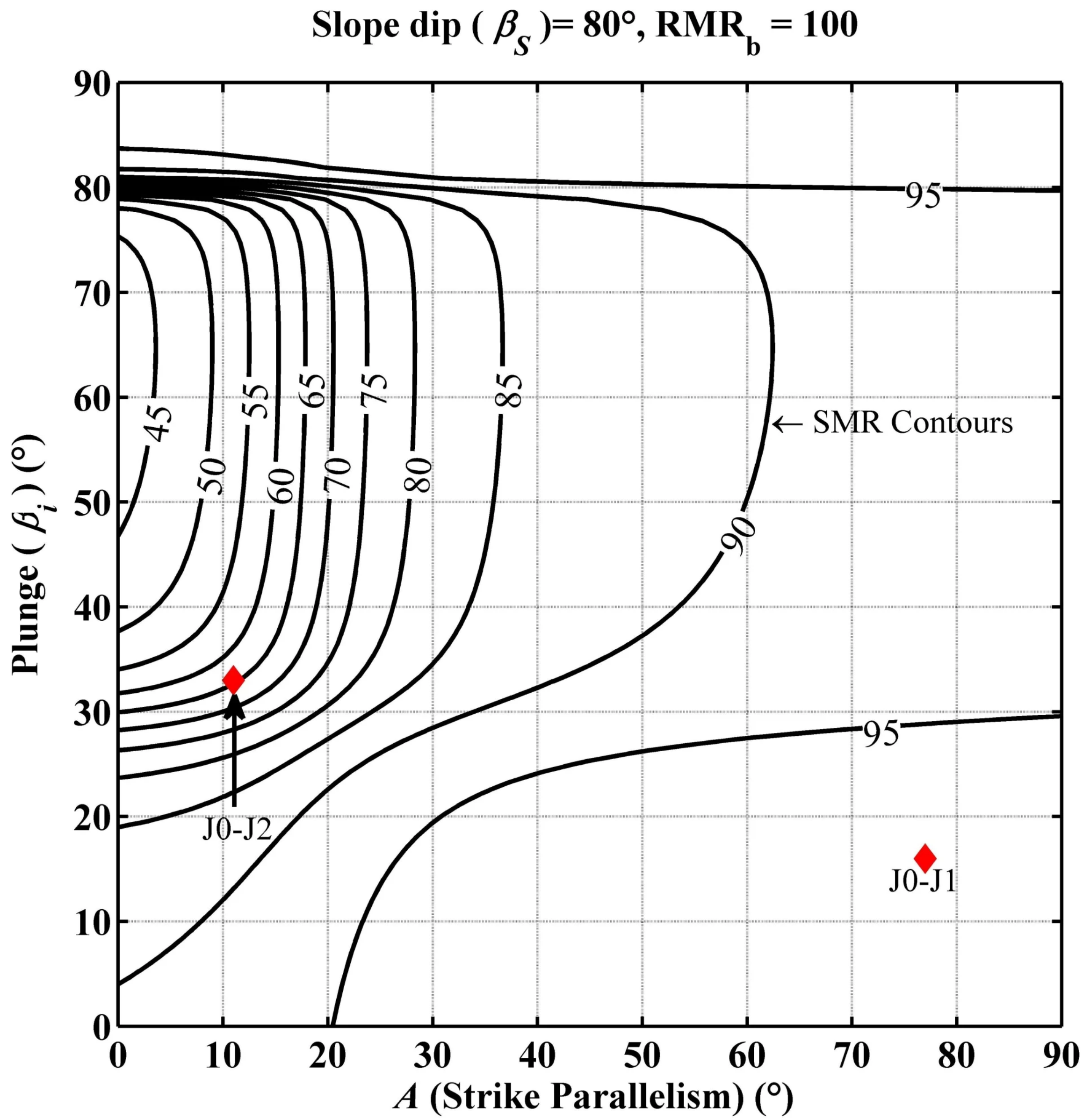

Figure 6b. Plunge (*βi*) vs strike parallelism |*A*| in case of wedge failure

- Toppling SMR calculation using SMR chart (Figure 6c):

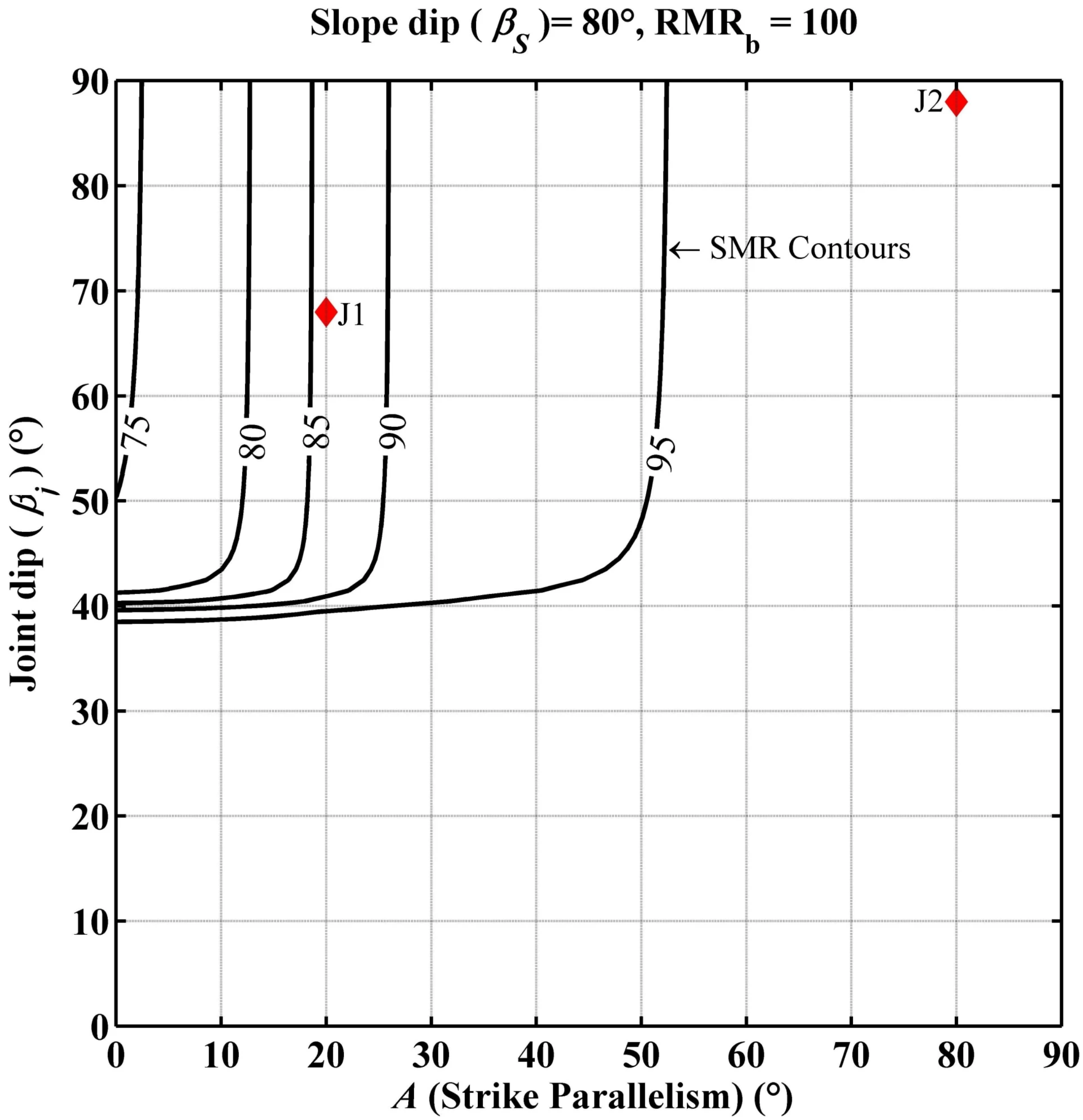

Figure 6c. Joint dip (*βj*) vs strike parallelism |*A*| in case of toppling failure

Figure 6a,b, and c concludes that minimum SMR value for the assumed slope lies in the range of 60-70 for wedge and planar failure case indicating Class II of SMR class as shown in Figure 7.

Class No.	V	IV	III	II	I
SMR	0-20	20-40	40-60	60-80	80-100
Description	Very bad	Bad	Normal	Good	Very good
Stability	Completely unstable	Unstable	Partially Stable	Stable	Completely stable
Failures	Big planar or soil-like	Planar or big wedges	Planar along some joints and many wedges	Some blocks	None

Figure 7. Various stability classes as per SMR values (after *Romana, 1985*)

CONCLUSIONS AND ACKNOWLEDGEMENTS

Main conclusions are pointed as:

- New SMR charts for the classification of rock slopes based on SMR class are proposed. The proposed charts can be used to estimate the SMR class of rock slopes directly in the field.
- In case of planar/toppling failure, discontinuity dip (βj), strike parallelism ($|A|$) between discontinuity dip direction (αj) and slope dip direction (αs) is plotted on the SMR chart.
- For wedge failure case, angle of the plunge of the intersection line of two sets of discontinuities (βi), strike parallelism ($|A|$) between the trend of intersection line (αi) and dip direction of slope (αs) is plotted on SMR chart.
- The SMR chart provides a rapid estimation of SMR class of rock slopes, which can be used for estimating reinforcement measures to stabilize road cut slopes during road widening work of the national highways in the mountainous terrains such as the Himalayas.

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The slope mass rating (SMR) method is universally used for the characterization and classification of rock slopes. SMR is calculated by reducing the value of basic rock mass rating (RMR_b) by substracting three adjustment factors F1, F2, and F3 based on the geometrical relationship between the slope and discontinuity and adding one adjustment factor F4 depending upon the excavation method used. These adjustment factors (F1, F2, and F3) are mathematical functions (continuous/discrete) that require post-processing of field data on a computer for their derivation. Less work has been done to develop the charts for the direct calculation of SMR in the field. In this paper, SMR charts are developed for the onsite classification of rock slopes. With the aid of SMR charts, an engineering geologist can easily assess the onsite SMR class of rock slopes by plotting discontinuity dip amount (plunge amount in case of wedge failure) and strike parallelism between slope dip direction and discontinuity dip direction (slope dip direction and trend direction of intersection line in case of wedge failure). Using SMR charts for any project (open-pit mines, road cut slopes, natural slopes, etc.) onsite suggestions of proper remedial and preventive measures for the rock slopes can be given, which accelerates the overall preliminary slope mass classification process. The proposed SMR charts are straightforward to use and can be adopted as useful tools for the preliminary rock slope stability assessment.

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